Establishment of odontometric sexual dimorphism in archaeological populations

Establishment of Odontometric Sexual Dimorphism in Archaeological Populations: A Case Study of Ḥasanlu

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Abstract

The accurate sex estimation in skeletal remains is considered to be an important step in the reconstruction of the biological profile of unknown individual in an archaeological context. Teeth are among the most frequently recovered human tissues that remain after death as they are hard, long lasting, and resistance to post-mortem insults. In general, males have larger teeth than females and this characteristic could be used in sex estimation. Present study aimed to investigate the degree of sexual dimorphism in the permanent teeth of Ḥasanlu, the Iron Age population in the Solduz Valley (West Azerbaijan Province of Iran). The Ḥasanlu site was excavated between 1956 and 1974 by a joined expedition of the University of Pennsylvania Museum of Archaeology and Anthropology, The Metropolitan Museum of Art, and Archaeological Service of Iran. The skeletal remains of Ḥasanlu are housed at the University of Pennsylvania Museum of Archaeology and Anthropology. In total, the collection consists of 263 individuals including 184 adults and 79 subadults. Analysis of the Ḥasanlu skeletal material was conducted from April to March 2014 and a total of 51 male and 33 female adult individuals belong to Iron Age levels (V, IV, and IVB) were used for sex estimation. The cervical mesiodistal and buccolingual measurements were collected from 299 upper and lower 3rd and 4th premolar teeth using Hillson-Fitzgerald dental calliper. Discriminant function analysis was used to evaluate the accuracy of each

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diameter in estimating sex. The mean cervical dimensions in all teeth of males exceeded that of females. The classification accuracy ranged from 74.6% to 85% with lower 4th premolar providing the highest accuracy rate (85%) and the upper 3rd premolar providing the lowest accuracy rate (74.6%). The results indicated that cervical measurements of the premolar is a reliable method for sex estimation and is useful to predict sex in Iranian archaeological populations.

Keywords: Sex estimation, cervical tooth measurements, premolars, Ḥasanlu

Introduction

Most studies on dental sexual dimorphism are based on the traditional mesiodistal and buccolingual crown diameters of teeth (Ditch and Rose 1972, Harris and Bailit 1987, De Vito and Saunders 1990, Acharya and Mainali 2007, Angadi *et al*. 2013, Khamis *et al*. 2014) (Fig. 1). In spite of the usefulness of these measurements, there are a number of limitations that impact their efficacy. The first limitation is the alteration of crown diameters due to the varying levels of expression of non-metric traits (Garn *et al*. 1968). When lower molars have extra cusps (e.g. cusp 6, cusp 7, protostylid), for example, the size of the overall tooth at the maximum dimensions of the crown increases. The second limitation, according to Hillson *et al*. (2005), concerns the difficulty that is normally met during measuring the mesiodistal crown diameters when the teeth are tightly fixed in the jaw. This is because when teeth are firmly wedged against the adjoining tooth, there is not enough space for the calliper points to be placed on the maximum convexity of the mesial and distal crown sides. Researchers, therefore, prefer to work with needlepoint callipers. In some cases, however, it is possible to slightly move the teeth in the jaw so that there is little access for measurements, but it is still nearly impossible to push the points far enough in. Also, there is a high risk of a delicate specimen being damaged very easily (Hillson *et al*. 2005). The third limitation, again as suggested by Hillson *et al*. (2005), is related to dental wear when recording the maximum measurement of contact points. Dental wear is the term used to describe a reduction in the size

of the tooth crown, which proceeds continuously during life (Wallace 1974, Hillson 2002, Koch and Poulsen 2009). As a result of dental wear, the crown diameters are altered and the recording of dental morphology is obscured. A moderate wear of the occlusal surface of the crown can lead to a significant decrease in the mesiodistal measurement. As with the buccolingual diameter, however, only excessive dental wear can affect it (Hillson 2002). In case of extreme dental wear, all the evidence of enamel is erased and the possibilities of making measurements or morphological identifications are eliminated. This is a common problem among archaeological skeletal samples. According to a study by Van Reenen (1982) when the crown is too worn away that the dentin is exposed, the percentage of the reduction in mesiodistal length could be as much as 10%. In case of secondary dentine exposure, this percentage could reach as much as 20% (van Reenen, 1982, Fitzgerald and Hillson, 2005). To solve these issues, alternative measurements of the cervical tooth diameters were proposed by Hillson *et al*. (2005). The authors defined the mesiodistal cervical measurement and the buccolingual cervical measurement as "the distance between the most occlusal points of the cement-enamel junction curve on the mesial and distal sides" and "The maximum measurement at the cement-enamel junction from labial/buccal to lingual/palatal" respectively (Fig. 1). Examining a total of 2559 unworn and isolated teeth, the authors reported that the cervical tooth diameters could provide similar results to those of crown diameters. According to their study, the impact of dental wear on these measurements is relatively small which first leads to a great increase in the sample size and makes it possible to compare heavily-worn teeth of adults against less-worn teeth of juveniles. The alternative dental measurements that Hillson *et al*. (2005) have proposed are specifically useful to take measurements where there is only a relatively small amount of enamel crown height available. This eventually allows access to mesiodistal diameters at the cervical-enamel junction, where the surrounding teeth can no longer obscure them when are still in the jaw. Moreover, given the location of the CEJ with respect to common non-metric traits of the crown, it seems likely that they would be less affected by non-metric trait expression. According to studies, these

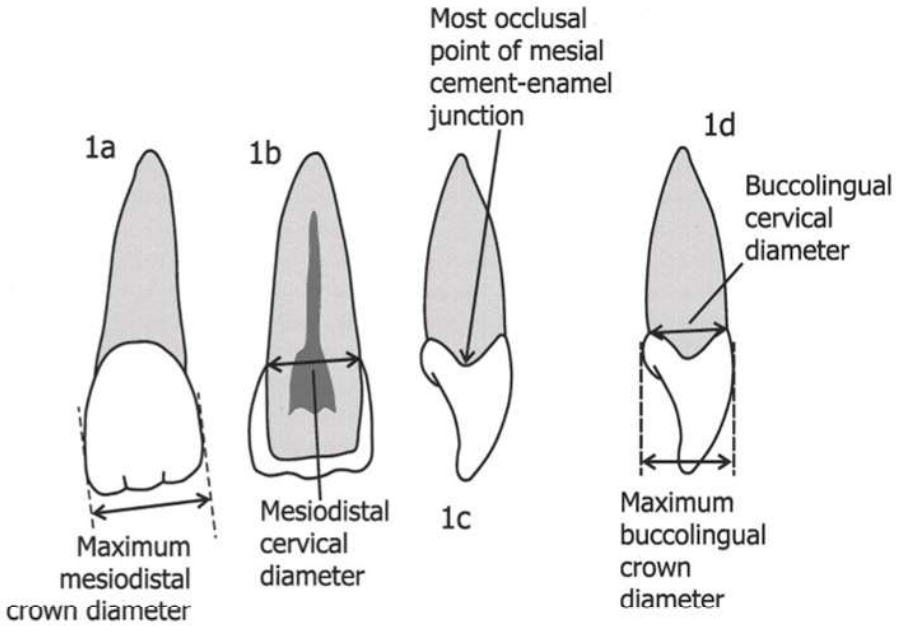

Fig. 1: Mesiodistal and buccolingual crown and cervical diameters (Hillson et al. 2005). 1a: Crown mesiodistal measurements, 1b: Mesiodistal cervical measurement, 1c: Mesial CEJ, 1d: Crown and cervical buccolingual measurements.

variables and those of tooth crown are highly correlated. Therefore, it can be concluded that they represent the same genetic expression of dental metric variation that tradition crown diameters do (Hillson *et al*. 2005, Stojanowski 2007).

Many studies have shown that canine is the most sexually dimorphic tooth in humans (Garn *et al*. 1977, Nair *et al*. 1999, Kaushal *et al*. 2003, Vodanovic *et al*. 2007, Hassett 2011, Viciano 2015). According to Garn *et al*. (1966, 1967) the teeth located adjacent to the canines (lateral incisors and third premolars) are more dimorphic than the others. Some studies on crown and cervical tooth measurements have also shown significant sexual dimorphism in permanent premolar teeth (Işcan and Kedici 2003, Zorba *et al*. 2011, Viciano *et al*. 2013, Sharma *et al*. 2014, Tuttösí and Cardoso 2015). Zorba *et al* (2011) conducted a study on 133

Greek individuals (70 males and 63 females) to measure the mesiodistal and buccolingual diameters of 839 permanent teeth. According to the results of this study, the most dimorphic teeth were the third premolar, maxillary forth premolar, and mandibular second molar following canine.

The purpose of current study was to analyse the cervical tooth measurements and examine the degree of sexual dimorphism in permanent premolars of an Iranian archaeological population.

Materials and Methods

This study was conducted on skeletal remains of 84 adults from Ḥasanlu site (West Azerbaijan, Iran) (Fig. 2) dating from 1450 to 800 B.C. Ḥasanlu skeletons are stored in the University of Pennsylvania's Museum of Archaeology and Anthropology (UPM), United States. In total 299 upper and lower permanent 3rd and 4th premolar teeth of 84 skeletons (51 males, 33 females) were studied. The sex of the skeletons was estimated using Phenice (1969) and Walker (2008) methods based on the morphological features of the pelvis and skull.

Tooth measurements in this study were taken as the mesiodistal and buccolingual premolar cervical diameters proposed by Hillson *et al* (2005) using Hillson-Fitzgerald dental calliper. Cervical measurements were taken from right upper and lower 3rd and 4th premolars. In the case of a missing value from the right side, the left antimere was substituted. A one way ANOVA was used to determine if there was any statistical significant differences between the mean values of males and females. Two paired t-test were performed to assess the interaobserver error of the measurements and also to check if there was any statistical differences between right and left side premolars. A discriminant function classification was then carried out to determine the relationship between osteologically estimated sex and premolar size measurements using software package SPSS version 23. A Leave-one-out classification procedure was also used to demonstrate the accuracy rate of the original sample and the one created by cross-validation.

Fig 2. Tepe Ḥasanlu is located in northwest Iran
(in the province of West Azerbaijan, south of Lake Urmia).

Results

To assess the intra-observer error, mesiodistal and buccolingual cervical measurements were collected from 80 randomly selected teeth from the original sample at a different time by the same observer. The paired t-test showed that the interaobserver error associated with the measurements was relatively low ($P < 0.05$) (Table 1).

One-way ANOVA showed that males have statistically larger teeth than females for upper and lower 3rd and 4th premolars and both measurements (Table 2). The paired t-test also showed that there was no statistically significant differences between right and left side teeth.

Table 1. Paired t-test evaluating intraobserver error in tooth measurements.

Measurements	N	Mean difference between measurements	Standard error of measurements	t-value[a]
3rd Premolars				
MD	40	0.00	0.03	0.25
BL	40	0.00	0.02	0.59
4th Premolars				
MD	40	0.00	0.02	0.79
BL	40	0.00	0.03	0.42

MD (mesiodistal)
BL (buccolingual)
[a] None of the t-values are significant at the $p<0.05$ level.

Discriminant analysis was conducted for each tooth and measurement separately. In total 12 discriminant functions were carried out. Classification accuracy of all functions is presented in table 3. It was seen that the accuracy ranged from 66.7% to 88.2% in males and 60.7% to 82.4% in females. The total classification accuracy for upper and lower 3rd premolars was 74.6% and 82.1% and for upper and lower 4th premolars was 75% and 85% respectively. Separate discriminant analysis was also performed for mesiodistal and buccolingual measurements. The results showed that the classification rates from mesiodistal dimensions were much better than that from buccolingual dimensions. The highest accuracy was obtained from mesiodistal diameter of lower 3rd premolar with a correct classification rate of 84.3% in males (Table 3).

In all functions the accuracy in males was greater than females. The only exception was function 10 –buccolingual diameter of upper 4th premolar-

Table 2. Descriptive statistics for 3rd and 4th premolar cervical measurements and the mean differences between the sexes

		Male			Female			
	Diameters	N	Mean	SD	N	Mean	SD	P
Upper 3rd premolar								
	MD	43	4.74	0.29	28	4.27	0.36	0.00
	BL	43	8.18	0.52	28	7.66	0.56	0.00
Lower 3rd premolar								
	MD	51	4.91	0.29	33	4.45	0.30	0.00
	BL	51	6.86	0.42	33	6.31	0.42	0.00
Upper 4th premolar								
	MD	38	4.85	0.33	26	4.44	0.30	0.00
	BL	38	8.48	0.61	26	7.75	0.65	0.00
Lower 4th premolar								
	MD	51	5.15	0.33	29	4.64	0.33	0.00
	BL	51	7.30	0.55	29	6.69	0.63	0.00

N: number of teeth, SD: standard deviation

which showed slightly higher accuracy on females (73.1%) than males (71.1%) (Table 3). The highest accuracy for sex classification (85%) was obtained for cervical diameters of lower 4th premolar (function 4). Discriminant analysis for mesiodistal diameter of lower 4th premolar (function 11) gave the next best classification accuracy followed by cervical diameters of lower 3rd premolar (functions 2 and 7). The lowest accuracy rate of assessing sex was obtained from buccolingual diameter of upper 3rd premolar with a correct classification rate of 60.7% in females (function 6).

Table 3. Accuracy of classification results of the original and cross-validated sample

Functions	Males	%	Females	%	Total average%
	N		N		
F1: UP3					
Original	43	76.7%	28	71.4%	74.6%
Cross-validated	43	76.7%	28	71.4%	74.6%
F2: LP3					
Original	51	84.3%	33	78.8%	82.1%
Cross-validated	51	82.4%	33	78.8%	81.0%
F3: UP4					
Original	38	76.3%	26	73.1%	75.0%
Cross-validated	38	76.3%	26	73.1%	75.0%
F4: LP4					
Original	51	88.2%	29	79.3%	85.0%
Cross-validated	51	86.3%	29	75.9%	82.5%
F5: UP3 (MD)					
Original	43	76.7%	28	71.4%	74.6%
Cross-validated	43	76.7%	28	71.4%	74.6%
F6: UP3 (BL)					
Original	43	69.8%	28	60.7%	66.2%
Cross-validated	43	67.4%	28	60.7%	64.8%
F7: LP3 (MD)					
Original	51	84.3%	33	78.8%	82.1%
Cross-validated	51	84.3%	33	72.7%	79.8%
F8: LP3 (BL)					
Original	51	70.6%	33	69.7%	70.2%
Cross-validated	51	70.6%	33	69.7%	70.2%
F9: UP4 (MD)					
Original	38	73.7%	26	73.1%	73.4%
Cross-validated	38	73.7%	26	73.1%	73.4%
F10: UP4 (BL)					
Original	38	71.1%	26	73.1%	71.9%
Cross-validated	38	71.1%	26	73.1%	71.9%

F11: LP4 (MD)					
Original	51	82.8%	29	82.4%	82.5%
Cross-validated	51	82.8%	29	80.4%	81.3%
F12: LP4 (BL)					
Original	51	66.7%	29	65.5%	66.3%
Cross-validated	51	66.7%	29	65.5%	66.3%

U: upper, L: Lower, MD: mesiodistal, BL: buccolingual

The cross validation test did not significantly change the original accuracy (Table 3).

Discussion

Dental sexual dimorphism has been long acknowledged (Garn *et al*. 1966, Ditch and Rose 1972, Hattab *et al*. 1997, Hillson *et al*. 2005, Hassett 2011, Zorba *et al*. 2011, Viciano *et al*. 2015, Tuttösí and Cardoso 2015), demonstrating that dental dimensions can be used successfully in sex diagnosis on both living individuals and skeletal remains.

In the present study, we used the cervical mesiodistal and buccolingual measurements of the upper and lower 3rd and 4th premolars for sex estimation. Studies on sexual dimorphism in tooth cervical diameters have shown that there are differences in tooth size between the two sexes and males usually have larger teeth than females (Vodanovic 2007, Viciano *et al*. 2011, 2013, 2015, Hassett 2011, Mujib 2014). This study also showed that upper and lower 3rd and 4th premolars were larger in males in both cervical mesiodistal and buccolingual dimensions.

Discriminant function analysis gave high classification accuracy for sex estimation (Table 3). The highest rate of accuracy was observed in cervical diameters of the lower 4th premolar (85%). This observation is in agreement with the studies conducted by Viciano *et al*. (2013) and Tuttösí and Cardoso (2015) which reported significant sexual dimorphism on lower 4th premolar. However, some studies on crown and cervical diameters have observed higher sexual dimorphism in

upper 3rd (Zorba *et al*. 2011, Sharma *et al*. 2014) and lower 3rd premolars (Işcan and Kedici 2003). The overall accuracy for sex estimation ranged from 82.4% in females to 88.2% in males (Table 3). Our study also suggested that mesiodistal dimension was more sexually dimorphic than buccolingual dimension based on univariate analysis.

A comparison between the two sexes showed that the classification accuracy of all functions was higher for males. This result is in concordance with other studies on cervical tooth measurements (Vodanovic *et al*. 2008, Hassett *et al*. 2011, Viciano *et al*. 2011, 2013, 2015, Zorba *et al*. 2011, 2013, Mujib *et al*. 2014, Peckmann *et al*. 2015). This means that females have a greatest disparity of teeth sizes and can more often be misclassified as male or that this observation is simply a result of the sample used in this study.

In conclusion sex estimation using dental cervical measurements in an Iranian population has proven to be accurate for both original and cross-validated data. This constitutes this method of significant value for application in unknown skeletal remains from Iran around the same period (Iron age); especially taking under consideration that they are most likely to survive harsh taphonomic conditions than any other skeletal element (Anderson *et al*. 1995, Vodanovic *et al*. 2007, Fereira *et al*. 2008). Cervical mesiodistal and buccolingual diameters of the teeth will allow an increase in sample sizes as they can be obtained from worn teeth or teeth still in the jaw.

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